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THE MANGANESE MINERALS OF A VEIN NEAR BALD KNOB, NORTH CAROLINA

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INTRODUCTION

One of the authors (C. S. R.) has been engaged in a study of the copper deposits of the southern Appalachian region, and in the course of that work has had opportunities to study mineral deposits of various other types in the region. One of the most interesting of these is a vein near Bald Knob, North Carolina, which is characterized by an unusual group of manganese silicates and oxides. This locality was visited in 1927, in company with Mr. E. B. Crabill of Galax, Virginia, who has long been interested in the geology and minerals of this region, and has often given his kindly and valuable assistance to visiting geologists.

A study of the minerals in the Bald Knob vein was begun in 1927, and Mr. Earl V. Shannon of the National Museum, made chemical analyses of the more interesting minerals. Optical and chemical data indicated the presence of at least one new mineral, but full confirmation required careful *x*-ray diffraction studies. These have now been completed and a final report can be made on the minerals of this vein. In the meantime, further work was done on the vein, and it has been visited (in May, 1931) by Mr. D. F. Hewett of the United States Geological Survey, in company with Mr. Crabill. Additional specimens and data on the vein were secured by Mr. Hewett and these have been a valuable help in completing this study.

The Bald Knob vein contains an unusual group of minerals, among which two are new. It also presents a most interesting problem in the paragenesis of hypogene manganese silicates, but only the mineralogy of the vein will be considered in this paper.

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LOCATION AND CHARACTER OF VEIN

The manganese vein is situated in Alleghany County, North Carolina, and has been prospected at a point about $1\frac{1}{2}$ miles (2.4 kilometers) south of the North Carolina-Virginia State line and 6 miles (9.6 kilometers) northwest of the southeast corner of the Wytheville topographic quadrangle. Independence, Virginia, is about 7 miles (11.26 kilometers) northwest and Sparta, North Carolina, about 3 miles (4.83 kilometers) southwest. Bald Knob, a small peak that rises to a height of 3,650 feet (1,112 meters), lies one-half mile (0.8 kilometers) northwest and New River is about $2\frac{1}{2}$ miles (4 kilometers) north from this locality. The region is a deeply dissected northward-dipping peneplain rising to an elevation of about 3,000 feet (914 meters) where the vein outcrops.

This part of Virginia and North Carolina was, in the 50's of the last century, a noted mining region that produced large supplies of copper from secondary ores. Sixteen miles northeast (25 kilometers) is the southwestern end of the Great Gossan Lead, a copper-bearing pyrrhotite vein 35 to 150 feet (10.7 to 49.2 meters) wide, and during mining activity, marked by mines scattered for 18 miles (29 kilometers) along its course. The Ore Knob copper mine of North Carolina is 16 miles (25 kilometers) southwest. Less important veins are the Peachbottom, a few miles south, and the so-called native copper lead to the east. The whole region was intensely prospected about 75 years ago, but manganese-bearing veins have not been previously reported.

Mr. Crabill reports that similar veins have been traced for over 20 miles (32 kilometers) by the gossan and, where prospected, they were found to lie parallel to, and almost in contact with, a lens of the pre-Cambrian Roan gneiss which follows the general strike of the foliated country rock, which is southeast. The vein is explored by a 60-foot (18 meter) inclined shaft which exposes a width of from 5 to 7 feet (1.5 to 2.1 meters). Oxides of manganese are the most abundant minerals to a depth of 10 feet (3 meters), but none persist more than 40 feet (15 meters), the depth at which the water table was encountered. Mr. Hewett made the following observations on the relationships in the unoxidized portion of the vein. The country rock strikes N. 45° – 50° E. and dips 50° to 60° SE. In contact with the southwest, or foot wall, is a lens of massive garnet about 2 feet wide (0.6 meter). Next is a lens about 1 foot (0.3 meter) wide composed largely of carbonate and the new mineral, alle-

ghanyite, but with lesser amounts of tephroite and the new spinel, galaxite. Next is a zone about 2 feet (0.6 meter) wide of massive garnet and in contact with the hanging wall a 3-foot (0.9 meter) zone of rhodonite, and lesser amounts of spessartite and tephroite. Of these lenses the one characterized by carbonate and the new minerals, alleghanyite and galaxite, is of greatest interest.

VEIN MINERALS AND THEIR GENERAL RELATIONS

The minerals of the Bald Knob vein, named in the order of their relative abundance, are as follows:

TABLE 1. HYPOGENE MINERALS OF THE BALD KNOB, N.C., MANGANESE MINE

Spessartite	Ferro or mangano (?) anthophyllite
Rhodonite	Actinolite
Calcite (manganiferous)	Phlogopite
Alleghanyite (new mineral)	Margarite
Tephroite	Chlorite
Galaxite (new mineral)	Apatite
Quartz	Pyrite
Magnetite	Pyrrhotite
Gruenerite	Chalcopyrite

The first eight minerals in the above list are the dominant ones of the vein and specimens can easily be found in which they are abundant. The others are commonly discernible only on microscopic examination.

The vein is very distinctly banded. This is best shown by narrow alternating lenses of the new manganese silicate, which it is proposed to call alleghanyite, and manganese bearing calcite. The tephroite and rhodonite also form wider but less sharply bounded lenses. The garnet, spessartite, which is the most abundant mineral of the vein, forms massive lenses and is also scattered through much of the rhodonite. The massive lenses of nearly pure spessartite have a maximum width of 2 feet (0.6 meter), and fine-grained yellowish spessartite forms irregular areas associated with manganese rich carbonate in rhodonite. Irregular areas of a brownish red, coarser grained garnet are closely associated with quartz. Rhodonite, the second mineral in relative abundance, forms at least one pure lens 10 centimeters wide, but it is more commonly intergrown with lenses of calcite and is cut by irregular masses of pale yellow spessartite, and vein-like areas of tephroite. Slightly pink, manganese-

bearing calcite is somewhat more abundant than alleghanyite, and forms nearly pure lenses, which alternate with that mineral or is irregularly disseminated through much of the rhodonite and tephroite. Red brown to bright pink alleghanyite forms lenses, many of which are not more than one millimeter wide, but a few reach 15 millimeters in width. The new mineral of the spinel group, which it is proposed to call galaxite, forms minute shining black grains which are commonly intergrown with alleghanyite. Magnetite and grunerite occur in close association and are commonly inclosed in fine-grained, granular quartz. The vein quartz forms pure masses that reach 5 to 8 centimeters in width, but associated with it are large areas of the coarse-grained, brownish red garnet, and lesser amounts of sulphides. The magnetite-quartz lens appears to be later and the vein quartz is clearly later than the manganese minerals. Alleghanyite and tephroite (an orthosilicate) are sub-silicic minerals and are chemically incompatible with quartz, so that obviously they could not form together. This is confirmed by sharp-walled veins of quartz which cut the manganese minerals. The sulphides are associated with quartz and it seems probable that the brownish red garnet also belongs to this generation of mineralization, and is distinctly later than the granular and massive spessartite. The actinolite, the ferro- or mangano-anthophyllite, phlogopite, and chlorite are secondary minerals that formed by alteration of the primary manganese silicates of the vein.

DESCRIPTIONS OF MINERALS

CALCITE

The manganese-bearing carbonate of the Bald Knob vein has been studied by Philip Krieger² by means of *x*-ray diffraction patterns and found to be a member of the calcite group, isomorphous with rhodochrosite. Most of the calcite is manganese bearing, but wide variations in the manganese content are indicated by the indices of refraction.

The following calculation of the various carbonate molecules present in a sample of coarse grained manganese-bearing calcite is based on a chemical analysis by J. J. Fahey, chemist of the U. S. Geological Survey:

² Krieger, Philip, Notes on an *x*-ray diffraction study of the series calcite-rhodochrosite: *Am. Mineralogist*, vol. 15, pp. 23-29, 1930.

TABLE 2. COMPOSITION OF CALCITE FROM BALD KNOB VEIN

MnCO ₃	42.17
CaCO ₃	56.31
MgCO ₃	1.71
FeCO ₃	0.08
Insol.	0.25
Total	100.52

TEPHROITE

GENERAL RELATIONS. Tephroite, the manganese olivine, forms anhedral, equidimensional grains that average 0.5 millimeters or less in diameter. They are gray in the hand specimen and colorless to slightly gray in individual grains. In thin section the mineral is colorless and without cleavage. Tephroite and alleghanyite both show equidimensional grains without cleavage, but the two do not occur together, and the color in the hand specimen and the complete absence of twinning in thin section distinguishes tephroite from alleghanyite.

OPTICAL AND PHYSICAL PROPERTIES. The optical properties of tephroite from the Bald Knob vein, together with those of tephroite from Franklin Furnace, are as follows:

TABLE 3. OPTICAL PROPERTIES OF TEPHROITE

	Bald Knob	Franklin Furnace, N. J. ³
Indices of refraction..	$\left\{ \begin{array}{l} \alpha = 1.785 \\ \beta = 1.803 \\ \gamma = 1.820 \end{array} \right.$	$\left\{ \begin{array}{l} 1.770 \\ 1.792 \\ 1.804 \end{array} \right.$
$\gamma - \alpha$	0.035	0.034
Dispersion.....	$\rho > \nu$	$\rho > \nu$
Axial angle.....	72°	large
Optical character.....	(-)	(-)
Specific gravity.....	4.082	
Hardness.....	6	

The optical properties given above for tephroite show that the indices of refraction of the Bald Knob material are only slightly higher than those for Franklin Furnace material. Otherwise the optical properties are similar.

³ Larsen, E. S., The microscopic determination of the nonopaque minerals: *U.S. Geol. Survey, Bull.* 679, p. 143, 1921.

The tephroite from this new locality has been studied by means of x -ray diffraction patterns and compared with samples from Franklin Furnace and Långban, Sweden. They were all found to be similar and are discussed and compared with the x -ray diffraction patterns of alleghanyite on page 10.

CHEMICAL COMPOSITION. The following analysis of tephroite from the Bald Knob vein has been made:

TABLE 4. CHEMICAL COMPOSITION OF TEPHROITE* FROM BALD KNOB, N.C.

SiO ₂	25.94
TiO ₂	None
Al ₂ O ₃	0.32
Fe ₂ O ₃	None
FeO	3.02
MnO	60.98
MgO	1.58
CaO	4.84
CO ₂	3.75
H ₂ O	0.34
	<hr/>
	100.77

* Earl V. Shannon, analyst.

The sample was obviously contaminated with carbonate. Since the carbon dioxide is just equivalent to the lime, the two are deducted together, although the carbonate doubtless contains some manganese and a little lime probably enters the tephroite. The tephroite, recalculated to 100 per cent after this correction, gives the following:

TABLE 5. RECALCULATED COMPOSITION OF TEPHROITE

	Per cent	Molecular proportions		Ratios
SiO ₂	28.24	468	468	95 or 1×95
Al ₂ O ₃	0.35			
FeO	3.27	20	999	204 or 2×102
MnO	66.42	936		
MgO	1.72	43		
	<hr/>			
	100.00			

Thus it corresponds very closely to the olivine formula, 2MnO·SiO₂.

ALLEGHANYITE

GENERAL RELATIONSHIPS. The most interesting mineral of the Bald Knob manganese-bearing vein is the new mineral, which it is proposed to call alleghanyite after the county in North Carolina in which it occurs. Its occurrence is similar to that of tephroite, but the two always form separate lenses that evidently formed under slightly different conditions although probably not at a distinctly different time.

In the hand specimen the color of alleghanyite is bright pink to grayish pink (from strawberry pink, 5.00 R.d. to vinaceous-rufous 7.R O.i, of Ridgway's color standard). Most of the mineral grains are imbedded in calcite and resemble garnets so closely that they were not distinguished until examined microscopically. These average about 0.5 millimeter in diameter, but a few reach a maximum diameter of several millimeters. Most grains are nearly equidimensional, rounded and somewhat etched, but very rarely a crystal face can be observed. Not more than two such faces have been observed on a single crystal, and therefore the crystal habit can not be definitely determined. The faces observable seem to represent pyramids and the general form suggests a nearly pseudo-isometric symmetry but the optical properties show that it is orthorhombic.

OPTICAL AND PHYSICAL PROPERTIES. The optical properties are given in the following table:

TABLE 6. OPTICAL AND PHYSICAL PROPERTIES OF ALLEGHANYITE

Indices of refraction.....	$\left\{ \begin{array}{l} \alpha = 1.756 \\ \beta = 1.780 \\ \gamma = 1.792 \end{array} \right.$
$\gamma - \alpha$	0.036
2V.....	72°
Dispersion of the axes.....	$\rho > \nu$
Optical character.....	(negative)
X = Acute bisectrix	
Z = Obtuse bisectrix	
Crystal system orthorhombic.	
Pleochroism not observable in thin section.	
Characterized by lamellar twinning.	
Sp. Gr.....	4.020
H.....	5.5
Fracture.....	Conchoidal

The pleochroism is not perceptible in thin section and only a slight pink color is observable. In thick grains the pleochroism varies from colorless, through pink, to light buff. The most striking property shown by alleghanyite in thin section is the almost in-

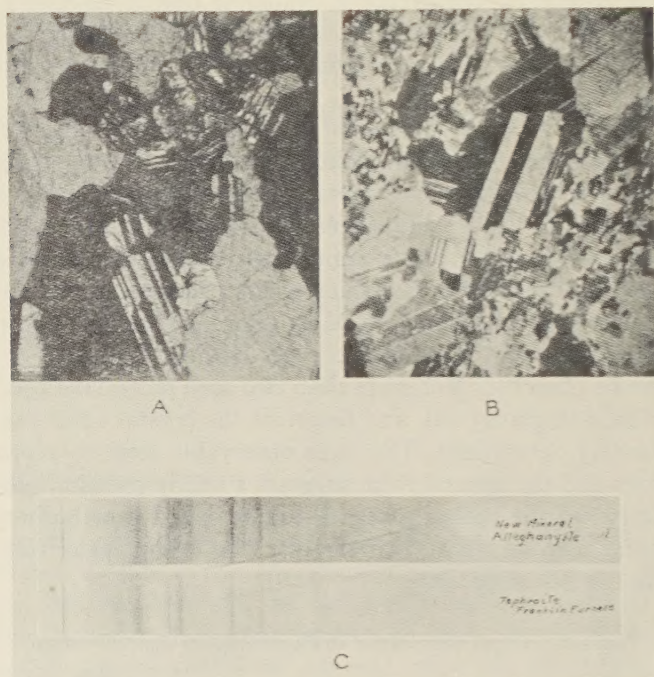


Plate I

FIGS. A and B. Photomicrographs of thin sections from Bald Knob vein. Twinned areas are the new mineral alleghanyite, and the black ones galaxite. The non-striated areas are manganiferous calcite.

FIG. C. X-ray diffraction patterns of tephroite, and new mineral alleghanyite.

variable presence of lamellar twinning, as shown in Plate I, Figs. A and B. Under the microscope the grains show no external crystal form and no cleavage, so that only the relation of the twinning to the optical directions of the crystal can be determined. Sections that show the maximum, symmetrical extinction on either side of the twinning plane are also perpendicular to the obtuse bisectrices of both individuals, and in such sections the angle of extinc-

tion is about 22° with the twinning plane. Extinction is symmetrical on the two sides of that plane in all sections cut perpendicular to the twinning plane, with extinctions varying 0° to 22° , and is parallel in all the sections cut perpendicular to a plane normal to the twinning plane. A section perpendicular to an acute bisectrix in one individual of a twinned crystal is 44° from perpendicular to the other individual and extinction in both is parallel to the twinning plane. The bilateral symmetry of the twinning in two perpendicular planes indicates that the mineral is orthorhombic.

CHEMICAL COMPOSITION. The mineral, alleghanyite, forms large brownish pink grains up to 5 millimeters in diameter and a hand-picked sample of these coarser grains is represented by analysis A. Smaller grains of bright pink color were used in making analysis B. These were intergrown with calcite and, very commonly, with the new spinel, galaxite. Grains free from galaxite were sorted by hand, recrushed, and the calcite removed by heavy solution. Standard methods of analyses were used and need no discussion.

The analyses and the molecular ratios calculated from them are given in the following table:

TABLE 7. CHEMICAL ANALYSES AND RATIOS OF ALLEGHANYITE

	Per cent*	Molecular proportions	Ratios	Per cent†	Molecular proportions	Ratios
SiO ₂	24.90	413 413	194 or 2×97	25.60	425 425	204 or 2×102
TiO ₂	none			trace		
Al ₂ O ₃	trace			1.50	15	
Fe ₂ O ₃	none					
FeO	1.40	19		1.62	23	
MnO	70.35	991	506 or 5×101	68.67	962	$1067 - 15$ $= 1052$
MgO	2.16	54		2.34	58	
CaO	0.74	13		0.24	24	
TOTAL	99.55			99.97		496 or 5×99

* Earl V. Shannon, analyst.

† F. A. Gonyer, analyst.

The material on which analysis B was made contained a small amount of the spinel, galaxite, and the Al₂O₃ and an equal molecular amount of RO bases are set aside as admixed spinel.

The two analyses agree very closely in giving a ratio of MnO

to SiO_2 of 5 to 2. Only small amounts of FeO , MgO , and CaO are present and the analyses conform very closely to the formula $5\text{MnO} \cdot 2\text{SiO}_2$.

COMPARISON OF TEPHROITE AND ALLEGHANYITE

Chemically this new manganese silicate is related to tephroite, the manganese olivine ($2\text{MnO} \cdot \text{SiO}_2$), but the manganese ratio is higher, that is, 5 to 2 for alleghanyite, while it is 4 to 2 (2 to 1)

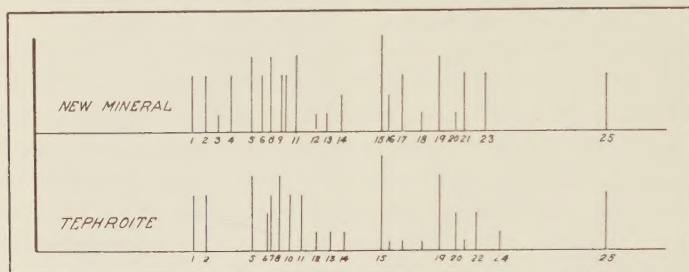


FIG. 1. Chart of the x -ray diffraction lines of the new mineral alleghanyite compared with tephroite. The line numbers refer to Table 8.

for tephroite. The mineral is remarkably fresh and so transparent that the possibility of admixture is excluded. No known primary manganese silicates are known whose admixture would increase the manganese-silica ratio over that of tephroite, and the black secondary oxides are visibly absent.

X-RAY DIFFRACTION PATTERNS. X -ray diffraction patterns of the new manganese mineral, alleghanyite, have been taken and compared with x -ray patterns of tephroite photographed under similar conditions of exposure. At the first glance the two sets of patterns might be thought to be the same. Careful observation, however, brings out a difference. Repetition of photographs, followed by measurement, further emphasizes their difference.

Tephroite patterns used for comparison with the new mineral were secured from samples originating in the following localities:

Långban, Sweden,
Franklin Furnace, New Jersey,
Sparta, North Carolina.

An x -ray diffraction pattern of the Franklin Furnace tephroite, which agrees with the tephroite patterns from the other localities, is shown in Plate I, Fig. C, together with a pattern of the new min-

eral. The patterns were secured with some difficulty, fine grinding and careful weighing of samples being necessary to produce patterns of even fair quality.

The patterns were taken under standard conditions of exposure, employing the K-alpha radiation of molybdenum and a zirconium oxide filter. The radius of film holder employed was 114.6 mm., and the two patterns were taken at the same time side by side in the same film holder.

A chart of the two patterns is shown in Fig. 1. Numbers are assigned arbitrarily to the lines in this figure, and same numbers are used in Table 8.

TABLE 8. COMPARISON OF X-RAY DIFFRACTION MEASUREMENTS OF TEPHROITE AND THE NEW MANGANESE MINERAL, ALLEGHANYITE

New Manganese Mineral, Alleghanyite			Tephroite		
Line No.	Est. Intensity	d in Å.U.	Line No.	Est. Intensity	d in Å.U.
1	f	3.94	1	f	3.94
2	f	3.64	2	f	3.66
3	fff	3.40		absent	
4	f	3.19		absent	
5	m	2.86	5	m	2.88
6	f	2.75	6	ff	2.70
	absent		7	f	2.66
8	m	2.64	8	m	2.56
9	f	2.53		absent	
10	f	2.475	10	f	2.46
11	m	2.375	11	f	2.345
12	fff	2.215	12	fff	2.215
13	fff	2.135	13	fff	2.115
14	ff	2.035	14	fff	2.025
15	s	1.800	15	s	1.810
16	ff	1.755	16	trace	
17	f	1.695	17	trace	
18	fff	1.620	18	trace	
19	m	1.550	19	m	1.550
20	fff	1.497	20	ff	1.497
21	f	1.463	21	trace	
	absent		22	ff	1.433
23	f	1.393		absent	
	absent		24	fff	1.357
25	f	1.110	25	f	1.110

Measurements of the interplanar spacings in Ångstrom Units are given in Table 8. Lines of approximately the same interplanar spacing in the two patterns have been assigned the same number. Lines are rated according to estimated intensity as follows: s—strong, m—medium, f—faint, ff—very faint, fff—measureable with difficulty, trace—may be detected but not measured,—and absent—entirely missing. The measurements have been corrected against similar films taken in film holders with sodium chloride.

Although the measurements for the two patterns are distinctly different it is interesting to note that there are a considerable number of lines in common in the two patterns. Several such instances of different substances giving somewhat similar patterns have been noted by various investigators. The classic example has been provided by the *x*-ray diffraction patterns of sillimanite and mullite which are so alike that they were at first described as being identical. The difference in the present instance, however, is much more noticeable than between sillimanite and mullite, and it is believed that the *x*-ray diffraction patterns clearly demonstrate a difference between the internal structures of the two minerals.

The indices of refraction of alleghanyite are $\alpha = 1.756$, $\beta = 1.780$, $\gamma = 1.792$; while those of tephroite are $\alpha = 1.785$, $\beta = 1.803$, $\gamma = 1.820$. That is, alleghanyite, the mineral with the higher manganese content, has the lower indices of refraction. This indicates that in tephroite there is a closer spacing of the atoms in the space lattice than in alleghanyite. This relation is confirmed by the specific gravities of the two minerals which are 4.086 for tephroite and 4.020 for alleghanyite. These values are very close together but the specific gravity is slightly higher for tephroite than for alleghanyite; that is, the mineral with the higher manganese content has a slightly lower specific gravity. It is difficult to accurately determine hardnesses, but alleghanyite appears to have a lower hardness than tephroite.

The foregoing descriptions of tephroite and the new manganese silicate show that they differ from one another in optical properties, in *x*-ray diffraction patterns, in chemical composition, and probably in the spacing of the lattice. This clearly differentiates the tephroite, the manganese olivine, from the mineral which it is proposed to call alleghanyite after the county in North Carolina in which it occurs.

ALLEGHANYITE FROM SAN JOSE, CALIFORNIA

A mineral with characteristics similar to alleghanyite has been described by Rogers⁴ from San Jose, California. The mineral occurred in an erratic boulder in which Rogers identified tephroite, hausmannite, pyrochroite, ganophyllite, rhodochrosite, barite, and psilomelane.

TABLE 9. OPTICAL PROPERTIES OF RHODONITE

	Bald Knob	Harstig mine
Indices of refraction.....	$\alpha = 1.723$	1.720
	$\beta = 1.727$	1.725
	$\gamma = 1.734$	1.733
$\gamma - \alpha$	0.011	0.013
Dispersion.....	$\rho < \nu$	
Axial angle.....	72°	75°
Optical character.....	(+)	(+)
Angles of extinction.....	$17^{\circ}30' \pm 30'$	
	$23^{\circ} \pm 1^{\circ}$	

Under the heading "tephroite," Rogers says,

Tephroite as a megascopic constituent of the ore is rare but in several specimens it was noted as a massive grayish red mineral which was at first thought to be rhodonite. . . .

The indices of refraction, determined by the immersion method, are greater than 1.740. Thin sections show almost colorless anhedral with interference colors ranging up to bluish-green of the second order, which proves that the double refraction is higher than that of rhodonite ($n_{\gamma} - n_{\alpha} = 0.011$) but lower than that of olivine ($n_{\gamma} - n_{\alpha} = 0.036$). Polysynthetic twinning is a prominent feature in the thin sections, a property not previously reported for tephroite. In some areas the twinning resembles an intergrowth of two minerals. The twinning is recognized largely by differences in interference colors rather than by extinction angles.

The grayish red color and the very characteristic polysynthetic twinning make it almost certain that the mineral from the San Jose boulder is identical with alleghanyite.

RHODONITE

GENERAL RELATIONS. Rhodonite forms pure lenses up to 10 centimeters in diameter and lenses of intergrown rhodonite and spessartite are even wider. Irregular and vein-like areas of rhodonite are included in tephroite. The dominant color is rhodonite pink (71''V-RR.d of Ridgway's color standard), but some areas are

⁴ Rogers, A. F., An interesting occurrence of manganese minerals near San Jose, Calif.: *Am. Jour Sci.*, 4th ser., vol. 48, pp. 443-449, 1919.

eosene pink (1 Red d). The largest grains are about 10 millimeters in length, but millimeter sized grains are more abundant.

OPTICAL PROPERTIES. The optical properties of rhodonite from Bald Knob and of material of similar composition from Harstig Mine, Pajsberg, Sweden, that has been studied by Hey,⁵ are given in Table 9.

CHEMICAL COMPOSITION. The results of a chemical analysis of hand picked grains of Bald Knob rhodonite are shown in the following table, and an analysis of the material from the Harstig mine

TABLE 10. CHEMICAL ANALYSES OF RHODONITE

	Bald Knob vein*			Harstig mine†
	Per cent	Molecular Proportions	Ratios	Per cent
SiO ₂	45.49	747	755	46.33
TiO ₂	Trace			
Al ₂ O ₃	0.78	008		0.26
Fe ₂ O ₃			788	0.83
FeO	3.74	052		n.d.
MnO	44.88	632		44.28
MgO	1.56	039		0.04
CaO	3.64	065		8.02
ZnO	Trace?		102×1	0.07
Ignition				0.22
Total	100.09			100.05

* Analysis by Earl V. Shannon.

† Analysis by H. H. Hey.

is included for comparison. This gives the formula $\text{MnO} \cdot \text{SiO}_2$, with the ratio of $\text{CaO}:\text{MnO}$ only about 1:10.

The analysis of the Bald Knob rhodonite reveals another example of a member of the rhodonite-bustamite series near the pure manganese end member. It is even lower in calcium than the Harstig material of Hey, but it is considerably higher in magnesium. Table 9 shows that the optical properties, including the positive optical character, are similar as would be expected from the chemi-

⁵ Hey, H. H., On the rhodonite-bustamite series: *Mineralogical Mag.*, vol. **22**, pp. 193-205, 1929.

cal composition, and confirms the conclusion of Hey⁶ that rhodnite-bustamite represents a completely isomorphous series including the pure manganese end member.

A NEW SPINEL, GALAXITE

GENERAL RELATIONS. A mineral that proves to be a new member of the spinel group is intergrown with alleghanyite and calcite. It forms rounded to euhedral grains that range from 0.01 to 0.5 and average 0.2 millimeter in diameter, and in the hand specimen the mineral is brilliant black and the streak is red-brown.

OPTICAL AND PHYSICAL PROPERTIES. The index of refraction of this spinel is $n = 1.923$. The color is mahogany red, 7.R-OL of the Ridgway color Standard. Sp. Gr. = 4.234, $H = 7.5$.

CHEMICAL COMPOSITION. The chemical composition is as follows:

TABLE 11. CHEMICAL COMPOSITION OF SPINEL FROM VEIN
NEAR BALD KNOB, N.C.*

	Per cent
SiO ₂	0.96
TiO ₂	Trace
Al ₂ O ₃	45.71
Fe, determined as FeO	16.36
MnO	34.03
MgO	1.50
CaO	Trace
ZnO	Trace?
	<hr/>
	98.56

* Earl V. Shannon, analyst.

With iron recalculated to give the spinel ratio, i.e. most of it recalculated to Fe₂O₃, we have present the following spinel molecules:

TABLE 12. MINERAL COMPOSITION OF SPINEL IN BALD KNOB, N.C.

Spinel MgO · Al ₂ O ₃	5.27
Hercynite FeO · Al ₂ O ₃	5.22
Jacobsite MnO · Fe ₂ O ₃	22.83
Galaxite MnO · Al ₂ O ₃	65.79
Quartz	0.96
	<hr/>
	100.07

⁶ *Op. cit.*

Thus the principal component is a spinel having the composition $\text{MnO} \cdot \text{Al}_2\text{O}_3$. This has not heretofore been described as a natural mineral, although it has been found as a furnace product and described by Krenner⁷ under the name "manganspinel." This name has not been recognized in the mineralogical literature and it seems best to give this distinct spinel an individual name. The town of Galax, Virginia, the home of Mr. Crabill, lies about 12 miles to the northeast, and in the Hillsville topographic quadrangle, that lies

TABLE 13. CHEMICAL ANALYSIS OF SPESSARTITE AT THE BALD KNOB VEIN*

Per cent		Molecular Proportions		Ratios	
SiO_2	35.04	581	581	194×3	96×3
TiO_2	Trace				
Al_2O_3	21.63	212	212	212×1	104×1
Fe_2O_3	None	—			
FeO	1.86	026	625	208×3	102×3
CaO	1.78	032			
MnO	39.83	561			
MgO	0.26	006			
	100.40				

* Earl V. Shannon, analyst.

immediately east of the Wytheville quadrangle in which the Bald Knob vein is located. The beautiful plant, galax, that is so widely used for holiday decorations and after which the town of Galax is named, grows abundantly in the region. Therefore, Galax seems to provide a suitable name and it is proposed to call this new spinel galaxite.

SPESSARTITE

GENERAL RELATIONS. The manganese-alumina garnet, spessartite, is an abundant mineral in the Bald Knob vein. Massive spessartite forms lenses up to 15 or 20 centimeters wide that are buff colored, and irregular masses and vein-like areas of fine-grained granular spessartite are abundant in rhodonite.

⁷ Krenner, J., Manganspinelle in der Hochofenschlacke von Menyhaza: *Zeit. f. Kryst. und Min.*, vol. 43, p. 474, 1927.

OPTICAL PROPERTIES. The indices of refraction of the garnets of the Bald Knob vein are as follows:

Fine-grained granular	$n=1.796$
Massive buff	$n=1.802$
Granular pink	$n=1.813$

CHEMICAL COMPOSITION. The chemical analysis shown in Table 13 has been made of the fine grained buff spessartite associated with carbonate and rhodonite. Calculated as mineral molecules and recalculated to 100%:

Spessartite	90.03
Almandite	4.36
Grossularite	4.82
Pyrope	0.79
	<hr/>
	100.00

The massive garnet has nearly the same indices of refraction and was formed under similar conditions, and so probably has a similar composition. The pink garnet appears to have formed at a later stage of mineralization and probably has a somewhat different composition as is indicated by the slightly higher index of refraction.

AMPHIBOLES

Three types of amphiboles have been observed in the Bald Knob vein. One of these is an orthorhombic variety that forms fibrous areas in rhodonite. The indices of refraction are $\alpha=1.653$, $\gamma=1.676$. These indices correspond to ferro-anthophyllite, but since it is a pink alteration product of rhodonite it is probably a mangano-anthophyllite. Rosettes of a monoclinic amphibole which have replaced calcite have the indices of refraction $\alpha=1.662$, $\gamma=1.675$. This is almost colorless even though the indices of refraction are rather high, and it, too, is probably manganese bearing. These two amphiboles are both secondary and are the result of later replacement of the primary minerals. The third and most abundant amphibole is grunerite, which is associated with magnetite.

MAGNETITE

Magnetite is associated with grunerite or quartz in lenses that reach 5 centimeters in width. It has not been completely analyzed;

but qualitative tests show that it contains about 0.3 per cent of manganese.

The other minerals need little discussion as they are sparse and add little to the knowledge of the vein. These are phlogopite, margarite, and chlorite and are all secondary minerals. The sulphides pyrite, pyrrhotite and chalcopyrite are associated with quartz and appear to be younger than the manganese silicates.

SUPERGENE MINERALS

The manganese silicates have undergone complete oxidation in the upper 10 feet only but show partial oxidation to about 40 feet. The most easily oxidized mineral is alleghanyite which is followed closely by tephroite. Rhodonite is readily oxidized, but somewhat less rapidly than these, and spessartite is more slowly altered. In the zone 10 to 20 feet below the surface spessartite merely disintegrates into fine sand. The spinel, galaxite, almost completely resists alteration and is an abundant inclusion in the oxidized ores.

The supergene manganese minerals that have been recognized are pyrolusite, wad, neotocite, and bementite. Intimate mixtures of pyrolusite and wad make up most of the oxidized material. Areas of neotocite, several centimeters across are characterized by glistening black color and conchoidal fracture. Microscopic examination shows that most of it is reddish brown and amorphous, but a part forms rosettes of bi-refracting material. The index of refraction is somewhat variable and ranges from 1.49 to 1.51.

Bementite forms dull brown radial, bi-refracting groups of crystals with an index of refraction of 1.65.

MONAZITE COLORED BY CARBON FROM
DICKENS TOWNSHIP, NIPISSING
DISTRICT, ONTARIO*

H. V. ELLSWORTH, *Canada Geological Survey.*

Some years ago there was considerable prospecting for feldspar and mica in the neighbourhood of Aylen Lake, and along the Parry Sound-Ottawa railway between Barrys Bay and Madawaska. Several pegmatite dikes were opened up, at least two of which produced feldspar for some time, and one dike on Aylen Lake is said to have yielded some 60 tons of muscovite. Radioactive minerals in small quantities frequently occur in this region, almost all the numerous dikes examined by the writer showing some indications of their presence. The monazite¹ described here was obtained from a dike on the claim of F. G. Armstrong of Pembroke, lot 9, conc. 13, Dickens Tp., probably on the north half of the lot. The dike strikes about N 60° E mag. along the side of a hill and is exposed for a length of 200 feet. The true width was not definitely ascertainable but it appeared to reach a maximum of 50 feet or more. To a large extent it consists of graphic intergrowth of quartz and microcline but patches of coarse crystal microcline and massive white quartz occur. Some good sized crystals of muscovite and biotite in less quantity occur, but as a rule the mica is so crumpled and cracked as to be valueless. Red garnets up to one inch in diameter are rather common in the feldspar, and a two inch crystal of molybdenite was seen. Small brilliant black crystals of a mineral resembling euxenite or samarskite are quite abundant in the feldspar in places, and occasional flat reddish brown crystals of monazite were seen. The crystal with which this paper is chiefly concerned was the largest specimen collected. It measured about three inches in one direction as indicated by the field sketch reproduced in Fig. 1. Unfortunately the mass was broken into fragments, some

* Published by permission of the Director of the Geological Survey, Canada.

¹ Monazite is not uncommon in the pegmatites of the Precambrian Shield but is almost invariably greatly altered. This particular material was selected for study because it was the only transparent monazite ever obtained in Canada, so far as the writer is aware, and consequently because of its very slight alteration would be of unusual interest in connection with radioactive age determination. The presence of carbon was not suspected at first, the color naturally being ascribed to iron or manganese.

of which were lost by the chiselling necessary to remove it from the rock and it was not possible to reassemble it completely. Fig. 2 is a photograph showing the best fragment recovered. The peculiar

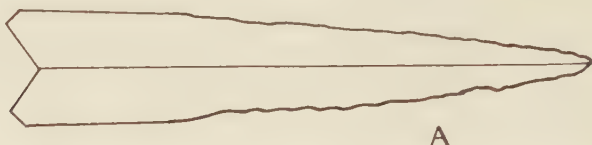


FIG. 1. Reproduction of field sketch showing outline of monazite crystal growth, natural size, as first seen embedded in pegmatite.

crystal habit exhibited by this monazite apparently has not been recorded hitherto. The whole crystal growth appears to be very complex. The two apparently simple, more or less symmetrical,

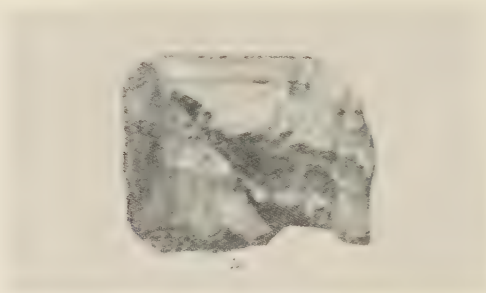


FIG. 2. Photograph showing part of monazite of Fig. 1, natural size after freeing from the rock. The front surface in the photo probably represents the top side of crystal growth seen in Fig. 1. The diagonal fracture from NW to SE seems to indicate a twinning plane between a parallel growth to the NE and a twin to the SW. The plane of fracture parallel to the surface of the paper thus appears to be common to a twin and a parallel growth. Unfortunately the part broken away from the SW front half, below the diagonal fracture, which would have given the key to the arrangement, was lost. Parallel growths are developed on the back of this mass.

halves of the mass are themselves twinned along a diagonal line as shown by the diagonal fracture in Fig. 2, and an examination of other fragments (Fig. 4) indicates a still more complex structure due to repeated twinning and parallel growth. The wide end of the tapering mass bears well developed crystal faces and is more or less transparent for a distance of about an inch back from the faces. The remainder becomes dark colored, in places almost black, to-

ward the thin edge of the wedge-shaped mass. The dark color has been found to be due to the presence of carbon in a state of very minute dissemination. In thin sections under the microscope the dark material does not appear to be different in any way from the transparent parts, except for the presence of some very minute dust like inclusions visible under high powers. That the dark color is due to carbon is indicated by the following observations: On

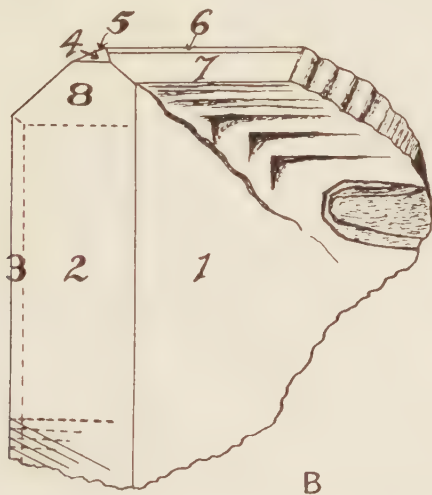


FIG. 3. Sketch showing details of crystal faces of Fig. 2, the diagonally fractured part of the mass being removed. Traces of what appears to be a good cleavage appear in the SW corner, the plane of which is at approximately 63° to 1 and the intersection on 1 normal to edges between 1, 2, and 3.

ignition of nearly black fragments before the blowpipe in air the mineral changes to a cream or yellow color. Crushed dark fragments packed in the bottom of a hard glass closed tube and similarly heated almost to a white heat do not lose their dark color, and no evidence of a distillate of heavy hydrocarbons condensed on the inside of the tube can be seen under the microscope, after drying out the water over sulfuric acid. A slight whitish ring of sublimate is produced which is probably lead oxide. The colors of certain minerals such as smoky quartz, purple fluorite and certain dark red feldspars, which are probably due to atomic disturbances induced by radioactive radiation, are discharged by heating to about 500° even in the absence of air, so these tests alone show that there is

no relation between the dark color of the monazite and that of smoky quartz. The best positive evidence that carbon is present, however, is obtained on heating 5 or 10 grams of the powdered mineral with sulfuric acid. The pasty mass thus obtained is brownish black in color and when diluted with water a very distinct brownish coloration and a brownish to black scum or precipitate is obtained, which is not affected by HCl but is destroyed by heating with concentrated nitric acid, or persulfates, or by ignition.

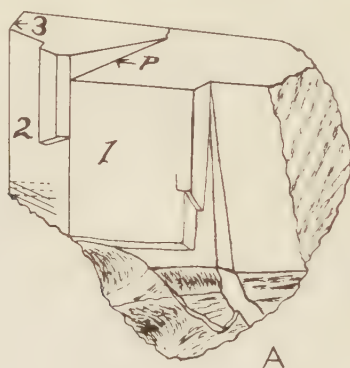


FIG. 4. Sketch showing another portion of the mass of Fig. 1, about natural size $P \wedge 2 = 68^\circ$. Approximate polar angles $1 \wedge 2 = 40^\circ$, $2 \wedge 3 = 87^\circ$, P is a plane following the intersection of 1 and 2 along which the mass has separated into two parts. The top of the drawing represents the mass as though it were smoothly sectioned in order to give a better idea of the form; actually it is irregularly fractured in a way having no apparent crystallographic significance. A good cleavage as indicated is developed at the SW corner.

The sulfuric acid used when heated alone did not become colored in the least, and if the powdered mineral is ignited at a red heat in air before treatment with sulfuric acid no brown coloration or scum is produced. Finally several grams of the powdered mineral were ignited in a current of CO_2 -free oxygen, observing all the precautions incident to a quantitative carbon determination, the emerging gases being passed through barium hydroxide solution with the result that a very distinct and unmistakable precipitate of barium carbonate was produced. This test of course does not necessarily prove that carbon as such is present, since rocks and minerals often contain CO_2 and CO as gas inclusions, occluded, or otherwise, but nevertheless it furnishes confirmatory evidence. Thus it appears that the dark color is certainly due to carbon—not hydro-

carbons—disseminated as extremely minute particles, some of which are possibly of atomic dimensions since reactions for carbon can be obtained even from the clear transparent material in thin sections of which not the slightest visible evidence of the presence of carbon can be detected, using magnifications up to 400 diameters and arc light illumination. Even selected fragments of the very finest perfectly transparent material which are normally a deep reddish brown color become almost colorless on ignition in air, exhibiting only a faint yellowish tinge. Thus there is reason to believe that the normal reddish brown color of the transparent portions is also due to carbon present as particles of such small size as to be invisible under the microscope. It might be mentioned that the alteration along cleavages and cracks shows up much more clearly after the mineral has been ignited, as an opaque whitish to yellow, or even reddish film, while the clear transparent areas remain unaffected except for the loss of color as previously noted. In spite of the marked reactions just described it is not likely that the carbon constitutes more than a few hundredths of a per cent of the dark material, at most, probably less. No quantitative determination was attempted on the sample analyzed which consisted of the best selected clear reddish brown material and contained much less carbon than the dark parts.

The association of carbon and hydrocarbons with radioactive minerals is not unusual in the pegmatites of Ontario and Quebec studied by the writer. The present case, however, is interesting in that we have here a transparent mineral which is definitely proved to be colored by carbon.

CRYSTALLOGRAPHY

A small crystal one quarter inch in diameter (Figs. 5, 6) was measured on the two-circle goniometer in various orientations. A projection using the large front face (Fig. 5) as base came out in fairly good agreement with published data (Goldschmidt), indicating the presence of the faces: $c(001)$, $a(100)$, $m(110)$, $X(101)$, $V(\bar{1}\bar{1}1)$ and $*(0\bar{3}2)$. However, as may be seen from the photograph the faces of even this small crystal are too distorted and imperfect to permit accurate measurement. The large crystal (Figs. 1, 2, 3) appears to be similar in habit to the small one. Measurements with a contact goniometer on the faces shown in the drawing (Fig. 3) gave the following approximate values for polar angles: $1 \wedge 2 = 57^\circ$,

$2 \wedge 3 = 87^\circ$, $2 \wedge 4 = 39^\circ$, $1 \wedge 7 = 47^\circ$, $1 \wedge 6 = 63^\circ$, $5 \wedge 6 = 57^\circ$, (5 is very narrow, rough and rounded), $7 \wedge 8 = 92^\circ$. On the small crystal faces (001) and (032) apparently correspond to 1 and 7, respectively, on the large crystal, and (001) and (101) agree with 1 and 2 to within 3 or 4 degrees, but the measurements seem to be sufficiently accurate in this case to demonstrate that this difference of 3 or 4



FIG. 5. Photograph of small, simple monazite crystal (same locality) measured on goniometer, actual size $\frac{1}{4}$ inch diameter. The large front face is believed to be $c(001)$, face at the left (032), at NW corner $m(110)$ and $V(111)$, top $a(100)$ and $X(101)$. Lower part of photo shows mounting wax holding crystals.

degrees actually exists. Both crystals are wedge shaped, the angle between 1 and the corresponding face behind being about 2 or 3 degrees.

The writer's thanks are due Dr. Eugene Poitevin for collaboration in attempting to work out the crystallography of this mineral.

OPTICAL PROPERTIES IN RELATION TO HOMOGENEITY

Both the transparent and dark colored portions of the crystal were examined in representative thin sections to discover, if possible, evidences of alteration or the presence of inclusions. If, as has sometimes been supposed, the thorium is present in the form of thorite as inclusions or intergrowths, the thorite should make up

9.09 per cent of the whole material ($7.32 \text{ ThO}_2 + 1.77 \text{ SiO}_2$), if the full amount of silica were present. Actually, however, only 1.54 per cent of silica was found by analysis. Thorite is always isotropic and should be easily detected between crossed nicols, but no indications of isotropic inclusions could be seen. A prominent cleavage or parting is well shown in all the sections as a series of roughly parallel rather closely spaced lines of cracks. Along the edges of these major fractures the clear monazite has altered to a cloudy whitish material scarcely noticeable with strong illumination but

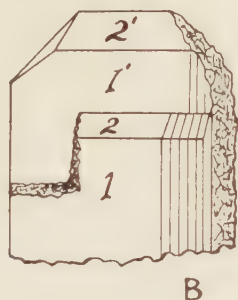


FIG. 6. Sketch of opposite side of crystal shown in Fig. 5, showing parallel growth. Faces 2 and 2' are rough but apparently parallel. Approx. polar angles $1 \wedge 2$, $1' \wedge 2' = 47^\circ$. A good cleavage is developed on the R. H. side of the front individual as indicated by the parallel lines. This was measured on the two circle goniometer and found to be $104^\circ 45'$ to face 1.

very distinctly visible when the right conditions are obtained. Just as in the case of many titano-columbate minerals examined by the writer this alteration could easily account for the silica present without assuming the presence of thorite. The mineral also shows a rather definite parting or rough cleavage across the major cleavages and in addition a still more minute system of irregular minor fractures may be seen under high powers with certain conditions of illumination. The alteration seems to vary directly with the size of the cleavage cracks or fractures, being scarcely apparent along the more minute fractures. Apart from the whitish alteration product visible chiefly along the major fractures, the only indication of a possible lack of homogeneity is a variation in the interference colors producing a mottled effect of red and blue. All the sections were apparently a little thick and the predominant color over the greater part of the section was a pale permanganate pink, probably

representing the second order, while the thinnest edges were pale yellow, succeeded higher up by the red of the first order. The permanganate pink is mottled with blue spots apparently of the first order. The blue spots may possibly represent areas in which the mineral has a lower birefringence, or they may represent lower spots where the abrasive perhaps has ground softer altered areas to a greater extent than the parts represented by permanganate pink, or these spots may merely be places where the abrasive has torn off larger flakes of the mineral than usual. Viewed obliquely under a binocular microscope the surfaces of the sections appear rather rough and pitted, lending weight to the last explanation as being the most probable. The blue areas do not appear to be related in any way to the major cleavages. It appears certain, however, that thorite is not present and that the silica can be accounted for by the alteration along the major cleavage cracks.

SUMMARY

The mineral is reddish brown to black, transparent to opaque, anisotropic. Shows one good cleavage (?) and a parting normal to the cleavage. Lustre vitreous, fracture subconchoidal to uneven, $H = 5.5$, Sp. Gr. = 5.270. In wedge shaped complex crystal growths.

The sample for analysis was carefully selected from the best transparent material. Lead, uranium and thorium were determined on 5 and 10 gram lots. The analysis yielded results as follows:

MONAZITE, DICKENS TOWNSHIP, NIPISSING DISTRICT, ONTARIO

PbO (Pb=0.31).....	0.33
U ₃ O ₈ (U=0.27).....	0.32
ThO ₂ (Th=6.43×0.38=2.44 U equiv.).....	7.32
Ce ₂ O ₃	22.63
(La, Di) ₂ O ₃	34.63
(Yt, Er) ₂ O ₃ ...	4.66
CaO.....	0.35
MgO.....	0.02
Fe ₂ O ₃	0.08
MnO.....	Not detected
Al ₂ O ₃ , etc.....	<0.10
P ₂ O ₅	27.89
SiO ₂	1.54
H ₂ O-110°.....	0.06
H ₂ O+110°.....	0.34
He, etc.....	Not determined
C.....	Traces present
	<hr/> 100.27

$$\frac{\text{Pb}}{\text{U} + 0.38 \text{ Th}} = 0.11$$

Sp. Gr. = 5.270 at 20.65°

Monazite is a particularly interesting mineral considered as a geological age indicator and in connection with the theories of radioactive disintegration because, according to most of the published analyses, it contains thorium but no uranium. Minerals in which thorium is present unaccompanied by uranium are rare, if indeed any such exist. It seems likely that in the older analyses of monazite small amounts of uranium actually present may have been overlooked or at least not determined. Thorium minerals compared with uranium minerals usually yield low age results and various theories have been proposed to account for this. At one time it was thought that possibly the lead is unstable, or that there may be another end product besides lead, but the tendency at present is to ascribe the low lead ratios of thorium minerals to loss of lead due to alteration and leaching. Holmes has advanced a plausible explanation of the discrepancies by supposing that the lead of uraninite is present in the mineral as uranate while in thorium minerals more particularly thorites and thorianites, it must be present as oxide or other compound, and that the lead uranate is less soluble and less liable to be leached away than the lead compound occurring in thorium minerals. On the other hand, lead phosphate which might be formed in monazite, is a very insoluble compound. The writer has shown that complex U, Th, titano-columbate minerals which contain appreciable silica due to alteration yield low lead ratios, while those with little or none are in accord with uraninite. It is interesting to note that almost all monazite analyses show a silica content of one per cent or more, and it has been supposed that the silica could be accounted for along with the Th content by assuming thorite to be present as inclusions or intergrowths. But, as thin sections of the Dickens township monazite containing 7 per cent ThO_2 failed to yield any evidence of the presence of thorite, it seems more reasonable to believe that the silica found in monazite is due to replacement, involving loss of lead just as appears to be the case with the titano-columbate minerals. There is also, of course, in all cases where the lead ratio is too low the possibility that leaching may have removed not only lead but also radium and mesothorium, or other members of the radioele-

ments. If this were so it could be detected by determining radium and mesothorium by the emanation method and calculating whether they were present in amounts required by the normal equilibrium ratios to correspond with the amount of U and Th found by analysis.

KAOLINITE FROM THE TERMINAL MORaine OF STATEN ISLAND

PAUL F. KERR, *Columbia University.*

Isolated patches of white clay occurring in the terminal moraine of Long Island, Staten Island, and southern New Jersey have been mentioned in a number of geologic descriptions. Such an occurrence was recently encountered during excavation for a building site and samples were submitted to the mineralogical laboratory of Columbia University for identification by Messrs. Schoonmaker and Kirkman. Examination proved the clay to be composed essentially of kaolinite and muscovite. In view of the unusual occurrence, however, the clay appears to merit description. Recent studies¹ of clay minerals suggest that a review of a number of the early described occurrences of "kaolin" would be worth while. This paper is submitted as a part of such a program.

The clay outcrops along the west bank of a small creek about one-half mile southwest of Princess Bay Station on the Staten Island Railroad. The locality lies 100 yards north of Hylan Boulevard, and may be reached by following the west bank of the creek from the beginning of the west approach of the creek bridge on the boulevard. The creek cuts through the terminal moraine at this point and flows southeast into the head of Princess Bay, on the south side of Staten Island. (*Staten Island sheet, U.S.G.S. topographic map.*)

The excavation in which the clay was encountered penetrates the glacial till of the terminal moraine to a depth of thirty feet. The material overlying the clay is typical till of the type peculiar to the Staten Island section of the terminal moraine. It consists of loosely consolidated clay studded with boulders of variable size and is made up of a heterogeneous assortment of materials. The white clay occurs at the bottom of the excavation (Fig. 1).

The clay varies from a fraction of an inch to a foot in thickness

¹ Ross, Clarence S. and Kerr, Paul F., Dickite a kaolin mineral: *Amer. Min.*, vol. 15, No. 1, Jan. 1930, pp. 34-39. Kerr, Paul F., Kaolinite from a Brooklyn subway tunnel: *Amer. Min.*, vol. 15, No. 4, Apr. 1930, pp. 144-158. Ross, Clarence S. and Kerr, Paul F., The Kaolin minerals: *Jour. Amer. Ceram. Soc.*, vol. 13, No. 3, Mar. 1930, pp. 151-160, The Kaolin Minerals: *U.S. Geol. Surv., Prof. Paper*, 165E, pp. 151-180, 1931.

and in some places consists of a few thin seams an eighth of an inch thick interstratified with red sandy shale and grit. The material resembles white clay occurring near the base of the Raritan formation of the Cretaceous. When moist it has a soapy feeling and forms a closely compact layer. It is white in color with a slight tint of cream and contains numerous micaceous particles. Soft

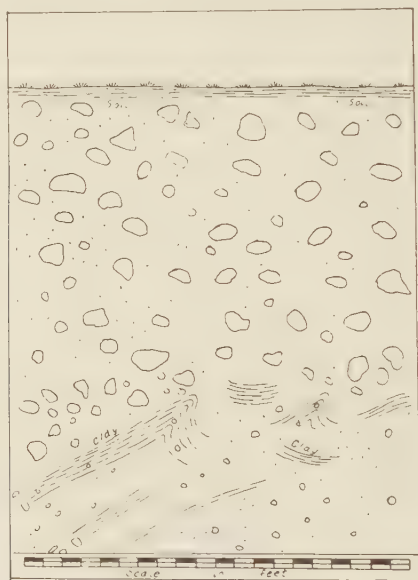


FIG. 1. Diagram illustrating the occurrence of kaolinite clay and sand beneath glacial till of the terminal moraine.

black carbonaceous material is in contact with the clay in a few places.

The exposure appears in irregular masses distributed over about ten feet in areal extent. The clay layers are decidedly irregular in stratification, are deformed and also are broken. In addition, they present the appearance of having been "plucked" loose from underlying strata and of having been transported a short distance from their original occurrence. Pockets of fine sand and also several irregular masses of gravel occur beneath the clay. These were uncovered by digging down several feet below the bottom of the excavation. A four-inch bed of red shale is also stratified in part parallel to the clay. Scattered through the white clay are isolated

pebbles composed of various sorts of rocks which stand out in marked contrast to the white clay which surrounds them. Thin lenses of sand likewise occur in the clay mass.

CLAYS DEFORMED AND TRANSPORTED WHEN TERMINAL MORaine WAS FORMED

Geologists have recognized for some time that the ice sheet which formed the terminal moraine along Long Island,² Staten Island³ and in New Jersey⁴ deformed and also transported blocks of clay belonging to the underlying Cretaceous strata. Merrill first called attention to this action in 1886. In a discussion of the geology of Long Island he stated:

We find the stratified gravels, sands and clays upheaved by the lateral pressure of the ice sheet and thrown into a series of marked folds at right angles to the line of glacial advance.

Hollick studied the phenomenon carefully and in describing the geology of Staten Island wrote as follows:

Throughout the morainal and stratified drift deposits . . . masses of clay or 'kaolin,' sometimes incoherent, sometimes more or less hardened by the infiltration and oxidation of iron, are prominent constituents. They are especially abundant in the morainal accumulations at Tottenville, Princess Bay and Arrochar. It is evident that where such material occurs . . . it represents masses and fragments which were eroded from strata . . . and carried forward either by the advancing ice front or by streams from the melting glacier.

MICROSCOPIC EXAMINATION

The washed clay is made up of fine matted kaolinite mixed with minute fragments of mica and feldspar.

The grains are so small that optical determinations are accomplished with some difficulty. The unwashed clay is highly impure.

Indices of refraction of the kaolinite as determined by the immersion method are n_{γ} 1.565(\pm .003) and n_{α} 1.560(\pm .003). The double refraction is about .006.

² Merrill, F. J. H., On the geology of Long Island: *Ann. N. Y. Acad. Sci.*, iii, 1886, pp. 341-364.

³ Hollick, Arthur, Dislocations in certain portions of the Atlantic Coastal Plain strata and their probable causes: *Trans. N. Y. Acad. Sci.*, vol. 14, Oct. 1894, pp. 8-20.

Hollick, Arthur, Cretaceous deposits of Staten Island: *U.S.G.S., Folio 83*, 1902, p. 10.

⁴ Ries, H., Kümmel, H. B. and Knapp, G. N., The clays and clay Industry of New Jersey: *Geol. Surv. New Jersey*, vol. VI.

Impurities identified beneath the microscope in the washed clay included muscovite, plagioclase, rutile, and hematite, together with traces of quartz and orthoclase. Muscovite and plagioclase were noted in sufficient quantity to suggest a recast of the chemical analysis.

A chemical analysis of the clay by Mr. A. M. Smoot of Ledoux and Co. is as follows:

	Per cent
H ₂ O at 100°C.....	.69
H ₂ O+110°C.....	11.46
SiO ₂	46.44
Al ₂ O ₃	36.36
Fe ₂ O ₃	1.25
TiO ₂	0.84
CaO.....	0.28
MgO.....	0.18
MnO.....	0.03
K ₂ O.....	1.50
Na ₂ O.....	0.42
	<hr/>
	99.45

The material selected for analysis was purified by washing and settling, only the slowly settling portion being utilized. It is evident from the analysis that in spite of the care taken in purifying the sample, constituents other than kaolinite remained in suspension. Microscopic examination of the sample as stated above brought out the presence of a small amount of fine mica and feldspar together with traces of other constituents.

Chemical work by Mr. Smoot showed that the sample did not contain more than traces of sulphur trioxide, carbon dioxide and phosphorus pentoxide. It contained some organic matter, presumably humus amounting possibly to two or three tenths of one per cent. All of the iron was reported as ferric oxide, the presence of humus vitiating the determination of iron in the ferrous condition.

In view of x-ray and optical work it seemed advisable to recast the above analysis in an endeavor to approximate the composition of the clay mineral constituent. The K₂O may be attributed to muscovite, the CaO and Na₂O to feldspar. The balance, aside from moisture above 110°C., silica and alumina, may be eliminated as due to various foreign constituents. The recast analysis of the clay

mineral constituent compared with kaolinite having the theoretical alumina-silica ration of 1:2 is as follows:

	RECAST ANALYSIS	THEORETICAL KAOLINITE
H ₂ O.....	13.81%	14.0%
SiO ₂	47.80	46.5
Al ₂ O ₃	38.39	39.5
	100.	100.

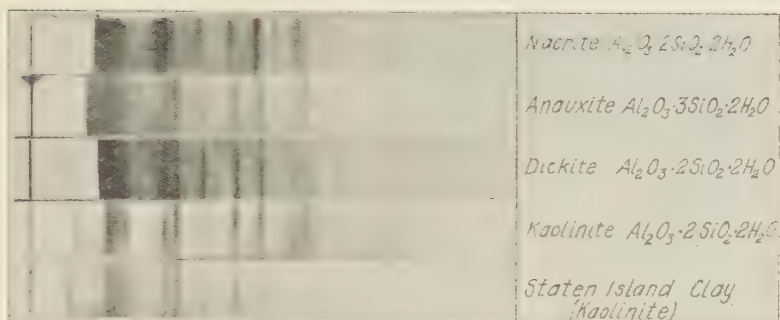


FIG. 2. An x -ray diffraction pattern of the Staten Island clay compared with x -ray diffraction patterns of Nacrite, anauxite, dickite and kaolinite. The Staten Island clay pattern agrees with either kaolinite or anauxite. The chemical composition, however, corresponds with that of kaolinite.

Although the material analyzed was impure, the analysis recast on the basis of eliminating impurities agrees with kaolinite.

X-RAY DIFFRACTION PATTERN

The x -ray diffraction pattern of the Staten Island clay corresponds to x -ray patterns of kaolinite. Extra reflections, due to the impurities in the clay remaining after washing, do not appear in some patterns or show as one or two lines in others. Such impurities were evidently not present in the washed sample in sufficient quantity to produce lines. Such a situation is not unusual in x -ray diffraction photography. X -ray diffraction measurements of kaolinite are already on record. A detailed description of residual kaolinite from Brooklyn may be used for reference. The x -ray pattern of the Staten Island clay is shown together with x -ray diffraction patterns of kaolinite, anauxite, dickite and nacrite in Fig. 2.

The reader is referred to recent descriptions of the kaolin minerals for further comparisons.⁵

SUMMARY

Microscopic examination, x -ray study and chemical analysis agree in establishing the identity of the clay mineral constituent as kaolinite. The occurrence of the clay suggests that it was picked from the base of the Raritan formation by passing ice of the Pleistocene glaciation, transported a short distance, and left in the terminal moraine. Although the clay mineral is kaolinite it is intimately mixed with fine feldspar and mica. Such clays have been recognized as "kaolin" for some time but the clay mineral has not previously been correlated with kaolinite according to the modern definition.

⁵ *Op. cit.*

A NEW METHOD OF BUILDING CRYSTAL STRUCTURE MODELS

JOHN W. GRUNER, *University of Minnesota.*

The construction of models of crystal structures presented no very great difficulties as long as the investigated structures were relatively simple, commonly cubic ones. One method was to slide metal rods into a heavy base board and to fasten beads or balls on these rods at proper intervals. Later more attractive models were made with wooden balls held together by metal rods which at the same time represented the coordinate valency bonds. The difficulty in constructing such models lies in the drilling of holes in the wooden balls at proper angles and in the centering of the balls during the drilling. Besides, with the coming of more complicated structures this method became so difficult and expensive that it is practically prohibitive now.

Sir William H. and Professor W. L. Bragg have introduced a new method of construction for complex structures.¹ In these models the valency coordinates are represented by thin glass tubes which are strung on copper or brass wires. Since such construction lacks support the most important positions of atoms are held in place by black metal rods stuck into a wooden base board. The centers of atoms at the intersections of the glass tubes are represented by balls of colored wax or other plastic material.

There are two objections to this construction. (1) The black supporting rods cause the already complex structures to appear even more so, and (2) the glass tubes are easily broken.

The writer thinks that he has a new method of construction which eliminates these objectionable features without introducing new ones. Brass rods are used to represent the valency bonds. These rods are soldered together. The junction points are positions of atoms and, therefore, are covered by balls after the completion of soldering. The balls are made from "plastic wood."² After the plastic wood has set the balls are painted, preferably with an enamel. These models are very rigid even when of large size.³ The

¹ Stereoscopic photographs of crystal models, edited by Sir William and Professor W. L. Bragg: Adam Hilger, Ltd., *London*, 1929, and 1930.

² Manufactured by Addison Leslie Company, Canton, Massachusetts.

³ The writer has constructed one with 300 atomic positions.

most convenient scale seems to be $1\text{\AA} = 30\text{ mm}$. If a smaller scale is used difficulty is experienced in reaching some of the positions inside of the model during the process of constructing the balls. The brass rods should be about $3/32$ of an inch thick which is a standard size, carried in stock. It can easily be bent in sharp angles if pliers are used.

In the building of a model, for example, of sillimanite,⁴ the following procedure may be adopted: A model of a unit cell of sillimanite with dimensions $a = 7.43\text{\AA}$, $b = 7.58\text{\AA}$, and $c = 5.74\text{\AA}$, will be about $22 \times 23 \times 17\text{ cm}$. in size. It is advisable to construct one which extends beyond the limits of one unit cell in order to show the interesting double chain bonds of SiO_4 and AlO_4 described by the writer.⁵ A plan of the atomic positions must be constructed first with the aid of the coordinate table by Taylor.⁶ The elevation of each atom above the plane of the paper (measured along the c axis) is written under each atom. Since Taylor gives the positions of the atoms of only one "molecule," the positions of those of the other three "molecules"—there are four in the unit cell—must be found by applying the operations of symmetry for the space group V_h ¹⁶ of sillimanite. A side elevation may be constructed in the same manner.

Now the coordinate bonds, that is the positions of the brass rods, are drawn on the plan. In sillimanite each Si is linked to the nearest four O. Half of the Al are linked to six nearly equidistant O, the other half to four O. An excellent check on the positions of the atoms in practically all oxygen compounds is the fact that O positions can not be closer than 2.5\AA to each other. The distance between O and Si should be not smaller than 1.5\AA .

It will be noticed in the plan that some of the atoms are linked in such a way that they lie in a plane parallel to the plane of the paper. These bonds can be bent from one piece of brass rod by taking the dimensions and angles directly from the plan. The angles and dimensions of other bonds are obtained by projecting the positions of the atoms on to the planes in which their bonds—and therefore the brass rods—are located. In this manner computations of angles and of directions can be avoided entirely. It is advisable to connect certain atoms which are really not linked together by

⁴ Taylor, W. H., The structure of sillimanite and mullite: *Zeit. f. Krist.*, vol. **68**, pp. 503–521.

⁵ Gruner, J. W., Structures of some silicates: *Am. Mineral.*, vol. **16**, p. 445, 1931.

⁶ *Op. cit.*, p. 512.

auxiliary brass rods during the time of construction. These rods can be easily cut away before the plastic wood is applied.

The soldering presents no difficulties even in places where four or more rods are to be joined if a good flux⁷ is used. Sometimes after a number of connections have been soldered it is found that certain rods can not be joined together on account of a slight cumulative error in angles or lengths of rods. It is, of course, very easy to unsolder some of the joints and correct the errors.

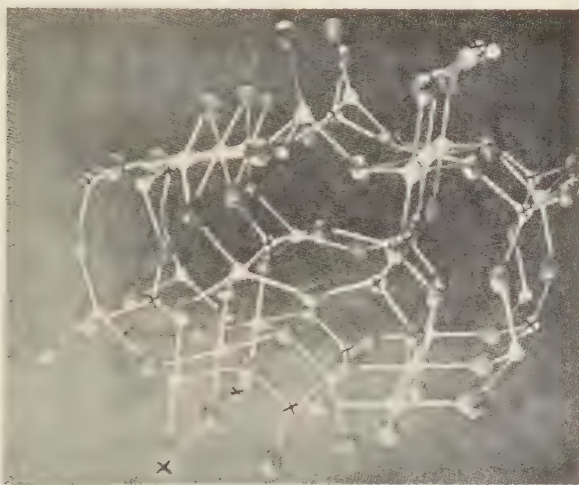


FIG. 1. Model showing the structure of sillimanite Al_2SiO_5 . Large balls are O, small white ones are Al, small ones with X are Si.

For best results the plastic wood should be put on in layers and not all at once for each ball. It would be almost impossible to make these balls perfectly spherical, but even imperfect ones look well after painting. The writer makes each element a different size. A brilliant red or some other bright color should be used for the most common atom—in silicates for oxygen—in the models. It adds to attractiveness and to visibility in a lecture room. Fig. 1 is a model of sillimanite as seen approximately in the direction of the c axis. The large balls are O ions. The small white ones with a black x are Si ions. On account of the reflection of light some of the brass rods appear much heavier than others in the photograph.

⁷ The writer found a solution of zinc chloride and denatured alcohol in the ratio of 1:1 very satisfactory.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, September 3, 1931

A stated meeting of the Philadelphia Mineralogical Society was held on September 3, with Mr. Toothaker presiding. Thirty-two members and twelve visitors were present. Mr. Stephen Varni was preposed for active membership.

The subject of the evening was *Reports of Summer Trips*. Dr. Alfred C. Hawkins described a visit to western North Carolina, and exhibited cyanite, beryl, emerald, almandite, actinolite, cassiterite, bornite, chalcopyrite, hyalite, uraninite, gummite, clarkite, cyrtolite, and inclusions of zoisite in muscovite.

Mr. Biernbaum described a trip taken with Messrs. Toothaker, Broadbelt, and Gordon to various localities in the Watchung Mountains of northern New Jersey, Bedford, and Tilly Foster, New York. The principal finds were: titanite crystals at Griggstown, pectolite at Paterson, jasper and copper at Somerville, pyrite in clay iron-stone at South River, pyrite and marcasite at Sayreville, stilbite at Summit, rose quartz at Bedford, and actinolite and talc at Mahopac. Dr. Oldach reported visits to the Wissahickon, and to the mines at Warwick, Hopewell, Dillsburg, and Boyertown. Mr. Flack spoke briefly of a visit to the Canadian Rockies. Mr. Knabe reported little success in working over the dumps of Wood's chrome mine. Mr. Toothaker reported on a trip with Mr. Boyle to Blue Hill and Brinton's quarries.

W. H. FLACK, *Secretary*

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, October 1, 1931

A stated meeting of the Philadelphia Mineralogical Society was held on the above date, with Mr. Toothaker presiding. Thirty-four members and sixteen visitors were present. Upon favorable recommendation of the Council, Messrs. Stephen Varni and William Wimer were elected members.

Mr. Toothaker spoke on *Collecting in New England*, descriptive of a trip taken during the summer with Mrs. Toothaker, and Messrs. Boyle and Gordon. The localities visited included the Trumbull tungsten mine, Connecticut, quarries near Portland and Middletown, Connecticut, the limestone quarries near Canaan, Connecticut, the emery mine at Chester, Massachusetts, the Westfield, Massachusetts, trap quarries, the Cumington, Massachusetts rhodonite mine, the marble quarries at Rutland, Vermont, the granite quarries at Barre, Vermont, the iron mines at Mineville, the garnet mine on Mt. Gore, and the graphite mine near Ticonderoga, in the Adirondacks, Ausable Chasm, Herkimer, New York, and Easton, Pennsylvania. Beautiful specimens of beryl, tremolite, garnet, rhodonite, quartz crystals, and datolite—an extraordinary mass of fine large crystals—were exhibited.

The following officers were elected: President, Dr. Florian Cajori; vice-president, Mr. Charles R. Toothaker; secretary, Mr. Wiley H. Flack; treasurer, Mr. Albert Hallowell; and councilor, Mr. William C. Knabe.

W. H. FLACK, *Secretary*

MINERALOGICAL SOCIETY OF SOUTHERN CALIFORNIA

The Mineralogical Society of Southern California was formed recently and held its first meeting on June 23 at the Pasadena Library, with an attendance of 175. The following were elected to hold office until June, 1932: President, Mr. John A. Renshaw; vice president, Mr. W. S. Morton; secretary, Mr. Edwin Van Amringe; treasurer, Miss Helen Fowler.

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

MINERALOGICAL SOCIETY, Nov. 4, ANNIVERSARY MEETING.

DR. F. C. PHILLIPS: *On crystals of brookite tabular parallel to the basal plane.* Small yellow-brown rectangular plates in heavy residues from Middle Jurassic sandstones of northeast Yorkshire are shown by optical and x-ray examination to be brookite of normal optic orientation, but unusual crystallographic habit, being tabular parallel to the basal plane. They are associated in the residues with brookite of normal habit, abundant anatase, and rutile.

PROF. T. ITO AND T. SHIGA: *On Scorodite from Kiura Mine, Bungo, Kiushiu, Japan.* The mineral occurs as small dark brown and green crystals associated with vivianite, fluorite, and quartz in druses in veins of arsenopyrite intruded into limestone. Chemical analysis on carefully selected material gives a result consistent with the formula $\text{FeAsO}_4 \cdot 2\text{H}_2\text{O}$. Forms present are (001), (100), (011), (120), (111), (201), (211), and (322). The crystals are orthorhombic with $a:b:c=0.865:1:0.972$. The habit is pyramidal equidimensional. The (111) faces show abundant vicinal faces belonging to two principal zones $[01\bar{1}]$ and $[10\bar{1}]$.

MR. W. CAMPBELL SMITH: *On a new meteoric stone from Suwahib, Arabia.* The stone was found on the sand near Buwah, in Suwahib, by one of the Arabs accompanying Mr. Bertram Thomas on his journey across the Rub'al Khali. As found it weighed just over 238½ grams. It is coated with limonite and shows no definite crust. It is a black chondrite belonging to Prior's Cronstad type, with over 10 per cent of nickel-iron. The density is 3.52.

DR. EDWARD S. SIMPSON AND MR. D. C. MURRAY: *A new siderolite from Bencubbin, Western Australia.* A mass weighing 119½ lb. (54 kg.) was found in 1930 near Bencubbin, about 150 miles northeast of Perth. It consists of a skeleton of nickel-iron (68.8%) with enclosed crystals up to 1 cm. across, of greyish-white enstatite (13.5%) and dark olivine (12.5%). In the metallic portion $\text{Fe:Ni}=15:1$. The meteorite is classed as a mesosiderite with an unusually high proportion of nickel-iron.

DR. A. R. ALDERMAN: *The meteorite craters at Henbury, Central Australia.* The locality is known locally as the Double Punch-bowl, from the two largest adjoining craters. It is situated 7 miles W.S.W. of Henbury cattle station on the dry Finke river, and about 50 miles south of the McDonnell Ranges in the very center of Australia. Within an area of 500 by 500 yards thirteen craters are mapped. The largest is oval in outline, measuring 220 by 120 yards across, and with a depth of 50 to 60 feet. The other craters are roughly circular with diameters ranging from 10 to 80 yards. The walls consist of powdered rock and shattered blocks of Ordovician sandstone and slaty rock. Owing to the craters acting as collecting pans for rain-water in this arid region, the spots are prominently marked by the growth of mulga trees, acacias, and course grass. Scattered around the craters are numerous pieces of metal-

lic iron, usually angular in shape, and ranging from a fraction of an ounce to $52\frac{1}{2}$ lb. in weight. In one arc of 6 by 6 feet over a hundred fragments were collected. Only two masses (one of 13 lb.) were found within the crater walls; and in one of the smaller craters a bore-hole to a depth of 8 feet through fine silt down to coarse rock fragments yielded no mass of iron. Fragments of iron rust are also abundant; and some glassy material, suggesting fusion of the country-rock, was found. These craters, which are very similar, were evidently formed by the impact of a shower of meteoric irons at some remote period.

ANNIVERSARY MEETING, *November 3rd.*, 1931. The following were elected officers and members of the Council: President, Sir John S. Flett; vice-presidents, Dr. G. F. Herbert Smith, Prof. C. Gilbert Cullis; treasurer, Mr. F. N. Ashcroft; general secretary, Mr. W. Campbell Smith; foreign secretary, Prof. A. Hutchinson; editor of the journal, Dr. L. J. Spencer; Ordinary members of council, Dr. A. Brammal, Mr. G. McDonald Davies, Prof. W. C. Fearnside, Miss M. W. Porter, Mr. A. F. Hallimond, Dr. F. H. Hatch, Sir Albert E. Kitson, Prof. W. L. Bragg, Mr. F. A. Bannister, Prof. H. H. Read, Mr. Arthur Russell, and Prof. C. E. Tilley.

BOOK REVIEWS

THE EXAMINATION OF FRAGMENTAL ROCKS, FREDERICK G. TICKELL. Stanford University Press, 1931. 122pp., 35 figs. and 2 pls. Price, \$5.00.

The examination of mineral fragments has proven to be a valuable procedure in petroleum geology, mining geology, hydrology, ceramics, metallurgy and in chemical engineering. Contributions to the science of mineralogy are being derived from each of these subjects. Prof. Tickell has endeavored to assemble some of the best methods from published contributions of each of these technologies. This material is presented in an unusually brief, compact form thus the errors of omission exceed those of commission. If, as the author states, the treatment is not one for elementary students, certain omissions become even more serious.

"Electric wind" effects are not mentioned under dielectric separation although such effects are vitally important. The maximum dielectric constants given in table 10 are meaningless without at least reference to temperatures at which they were obtained. More surprising is the omission of all methods for feldspar determination except those of Tsuboi and Schmidt. Surely advanced students are entitled to more than one page and one diagram on the fundamental conception of the triaxial ellipsoid. Mineralogists will be surprised to find the mixtures, leucoxene and limonite accorded full rank along with apatite and microcline as mineral species.

The chapters on size analysis and porosity and permeability are an excellent summary of the literature.

The book offers an elementary presentation to students of petrography even though it may be, as the author states, of advanced character to other students. Its chief value lies in the inclusion between two covers of material not otherwise to be found except by reference to many publications.

ERNEST E. FAIRBANKS

THE STUDY OF ROCKS. S. J. SHAND. xi+224 pages. Thomas Murby and Co., London, 1931. Price, 6 shillings. D. Van Nostrand Co. *New York*.

The author, who is professor of geology and mineralogy at the University of Stellenbosch, South Africa, quotes J. J. H. Teall upon the confusion in petrographic

nomenclature and the great number of names "used in different senses by different authors." He also repeats I. C. Russell's advice to use "plain English names" rather than Latin and Greek translations. Dr. Shand feels very strongly on these points which were first emphasized in his "Eruptive Rocks" published in 1927.

In the present volume, 129 pages are devoted to igneous (eruptive) rocks. We liked especially his brief summary of the various systems of classification of igneous rocks beginning with that of Zirkel, Rosenbusch, Harker, Hatch, Iddings, the Quantitative System by Cross, Iddings, Pirsson, and Washington, Osann, Niggli, Johannsen, and ending with his own which is a simplification using a combination of mineralogical and chemical characteristics in a system containing only 56 rock names. After his own classification, Dr. Shand evidently prefers that of Zirkel, but he is very fair to Rosenbusch whose adherents probably predominate in the United States and Canada.

From the perusal of the book we received the impression that the author is both a skilled petrographer and an efficient petrologist, and that he knows his literature exceedingly well. We also are aware that he knows the alkaline rocks of South Africa better than any other person. We will never forget our trips with him as guide during the Geological Congress of 1929, to the alkaline rocks of Pilandsberg, Franspoort, and Sekukuniland.

The book also devotes 48 pages to sedimentary, and 35 pages to metamorphic rocks. Instead of a long bibliography at the end of each chapter he gives "Suggestions for Reading" which are very pertinent. The reviewer has been very glad to read a book in English which has a different viewpoint, and also contains many expressions and words which differ from our usage in the United States.

FRANK R. VAN HORN

A DESCRIPTIVE PETROGRAPHY OF THE IGNEOUS ROCKS, VOLUME I, INTRODUCTION, FEATURES, CLASSIFICATION AND GLOSSARY. ALBERT JOHANNSEN. xxii+267 pages; with 146 illustrations. The University of Chicago Press, Chicago, 1931. Price \$4.50.

Petrographers will welcome this volume on the textures and classification of igneous rocks by Professor Johannsen, who is our leading scholar in this field. The chapters on the constitution, structures, and textures of igneous rocks are brief but with the Glossary of textural terms at the end they cover their fields adequately. One might question the explanation for the origin of spherulites and lithophysae, and the description of the large spodumene crystals at the Etta mine as crystallizations from a melt.

The main part of the volume is devoted to the classification of the igneous rocks. The subject is presented with a historical setting. The megascopic or field classification is hardly adequate or satisfactory for the purposes of a petrologist in the field. An unusual amount of space is devoted to chemical classifications and those of Osann, Hommel, Niggli and von Wolff, as well as the C.I.P.W. system, are described. It is refreshing to have these European classifications given equal weight with the C.I.P.W. classification in an American textbook.

An historical development of the mineralogical classification of igneous rocks is presented and the quantitative mineralogical classifications of Lincoln, Shand, Hodge, and in particular that of Johannsen are described. The classification of Johannsen has much to commend it. It follows very closely the commonly used system

of classification but is more systematic and more quantitative. It does this by using prefixes and other modifiers to the old terms so that one can readily understand the new rock names if he knows the names used in the prevailing classification. I believe that the double tetrahedron is over emphasized and that the scheme of classification is more easily understood from the tables than from the double tetrahedrons. It is to be hoped that petrographers will soon agree on a quantitative classification and I know of none that so well meets the needs of a working petrologist as that of Johannsen.

Nearly a third of the book is devoted to miscellaneous definitions and to textural terms. Chemical tables for the calculation of the norms and other purposes are given at the end. The values given for the specific gravities of minerals are misleading for while most minerals have a variable specific gravity it is incorrect to give the values for quartz as ranging from 2.649 to 2.697.

The book has real literary merit. The chapters are headed with apt quotations from many languages and one chapter is headed by the music of a song. A remarkable amount of information is presented in a clear, logical way in a small space. Very many references to the literature are given. The illustrations are numerous and excellent and include pictures of many of the leaders in petrography, illustrations of most of the important textures, numerous diagrams, etc. The printing paper and binding are of a high quality.

ESPER S. LARSEN